Appendix B

Radionavigation Systems Selection Considerations

B.1 Background and Approach

Many factors are considered in determining the optimum mix of Federally provided radionavigation systems. These factors include: operational, technical, economic, institutional and international parameters. System accuracy, integrity, and coverage are the foremost technical parameters, followed by system availability and reliability. Radio frequency spectrum issues also must be considered. Certain unique parameters, such as anti-jamming performance, apply principally to military needs but also affect civil availability.

The current investment in ground and user equipment must also be considered. In some cases, there may be international commitments which must be honored or modified in a fashion mutually agreeable to all parties.

In most cases, current systems were developed to meet different requirements. This resulted in the proliferation of multiple radionavigation systems and was the impetus for early radionavigation planning. The first edition of the FRP was published to plan the mix of radionavigation systems and promote an orderly life cycle for them. It described an approach for selecting radionavigation systems to be used in the future. Early editions of the FRP, including the 1984 edition, reflected that approach with minor modifications to the timing of events. By 1986, it became apparent that a final recommendation on the future mix of radionavigation systems was not appropriate and major changes to the timing of system life-cycle events were required. Consequently, it was decided that starting with the 1986 FRP, an updated recommendation on the future mix of radionavigation systems would be issued with each edition of the FRP. The 1999 recommendation reflects policy direction from the PDD (Ref. 2), dynamic radionavigation technology, changing user profiles, budget considerations, international activities and input received at radionavigation user conferences sponsored by DOT and DOD.

The Federal Government will solicit and consider inputs from users of radionavigation systems in the decision-making process on radionavigation systems. Developments in GPS augmentations and the changing user needs will be reviewed. The status and impact of commercial systems will also be considered as a part of this process. In addition, as an alternative to the phasing out of civil radionavigation systems, consideration may be given to the possibility of phasing over their operation to the private sector.

When the need or economic justification for a particular system appears to be diminishing, the Department operating the system will notify the appropriate Federal agencies and the public, by publishing the proposed discontinuance of service in the Federal Register.

In the final analysis, provision of Government services for meeting user requirements is subject to the budgetary process, including authorizations and appropriations by Congress, and priorities for allocations among programs by agencies.

B.2 Operational Considerations

A. Military Selection Factors

Operational need is the principal influence in the DOD selection process. Precise navigation is required for vehicles, anywhere on the surface of the Earth, under the sea, and in and above the atmosphere. Other factors that affect the selection process are:

- Flexibility to accommodate new weapon systems and technology.
- Resistance of systems to enemy interference or exploitation.
- Interoperability with the systems used by allies and the civil sector.
- Reliability and survivability in combat.
- Interruption, loss or degradation of system operation by enemy attack, political action, or natural causes.
- Availability of alternate means of navigation.
- Geodetic accuracy relative to a common reference system, to support strategic and tactical operations.
- Worldwide mobility requirements.

B. Civil/Military Compatibility

DOD aircraft and ships operate in, and must be compatible with, civil environments. Thus, there are potential cost advantages in the development of common civil/military systems.

The activities experienced in activation of the maritime Ready Reserve Force during Desert Shield/Desert Storm have identified a potential need for improved navigation

accuracy for ships involved in military sealift support. New GPS receiver concepts for systems with optional security modules are under consideration to be used when commercial ships are called into use in national emergencies.

C. Review and Validation

The DOD radionavigation system requirements review and validation process:

- Identifies the unique components of mission requirements.
- Identifies technological deficiencies.
- Determines, through interaction with DOT, the impact of new military requirements on the civil sector.
- Investigates system costs, user populations, and the relationship of candidate systems to other systems and functions.

B.3 Technical Considerations

In evaluating future radionavigation systems, there are a number of technical factors which must be considered:

- Received signal strength
- Spectrum availability
- Multipath effects
- Signal accuracy
- Signal acquisition and tracking continuity
- Signal integrity
- System availability
- Vehicle dynamic effects
- Signal coverage
- Noise effects
- Propagation
- Susceptibility to radio frequency (RF) interference (natural or man-made)
- Installation requirements
- Environmental effects

- Human factors engineering
- Reliability

B.4 Economic Considerations

At the present time, there are several systems being operated by FAA, USCG, DOD and others. The Government must continually review the costs and benefits of the navigation systems it provides. This continuing analysis can be used both for setting priorities for investment in new systems, and determining the appropriate mix of older systems to be retained. Only those systems that serve a significant number of users and provide the economic benefits in excess of costs should continue in operation. In some cases duplicate systems will have to be maintained for safety reasons and to allow adequate time for the transition to newer more accurate systems; however, older systems must be evaluated to determine whether or not their level of use is cost-effective.

The benefits from Government-operated navigation systems include improvements in economic productivity, operating efficiency, and accuracy in determining location in a common coordinate system. These factors allow planning for more fuel efficient routes and can prevent inadvertent diversions from the planned routes. More precise location information can also be an important factor in preventing accidents. The efficiency benefits generally are the largest in dollar terms, but the safety benefits are very significant in justifying navigation systems.

In many instances aids to air navigation that do not economically qualify for ownership and operation by the Federal Government are needed by private, corporate, or state organizations. While these non-Federally owned/operated (non-Fed) systems do not provide sufficient economic benefit on a national scale, they may provide significant economic benefit to local economies. In most cases they are also available for public use. The FAA regulates and inspects the facilities in accordance with Federal Aviation Regulations, Part 171, and FAA directives.

The costs of navigation systems include capital investment, operating costs, and maintenance. These costs are borne by both the Government and the user. For new or replacement systems, the capital costs are significant. For existing systems, the operating and maintenance costs are the most important. Obtaining valid cost estimates is critical to analyzing the need for navigation systems.

Life cycle cost analysis is another important tool in decisions on navigation systems. Both DOD and DOT are aware of the need to minimize the life cycle costs in order to ensure the continued operation of navigation systems.

B.5 Institutional Considerations

The PDD supports enhancement of GPS for civil applications and acceptance and integration of GPS into peaceful civil, commercial, and scientific applications worldwide. In order to accomplish this, there is a need to work with Congress, and all other interested

parties, to develop a comprehensive, continuing and reliable funding program for the transportation navigation and positioning infrastructure.

A. Cost Recovery for Radionavigation Services

It has been the general policy of the U.S. Government to recover the costs of Federally provided services that provide benefits to specific user groups. The amount of use of present Federal radionavigation services by individual users or groups of users cannot be easily measured; therefore, it would be difficult to apportion direct user charges. Direct user charges normally involve a fee for each use of a specific system. Cost recovery for radionavigation services is either through general tax revenues or through transportation trust funds, which are generally financed with indirect user fees. These fees usually take the form of a fuel tax or value-added tax and can be used to pay all or part of an agency's costs. In the case of GPS, the PDD has stipulated that there will be no direct user fees for GPS SPS.

Currently, the DOD and USCG operated systems are financed with general tax revenues. Aviation navigation systems are purchased with trust fund revenues and the systems are operated with a mix of general tax funds and trust funds. Introduction of GPS services has greatly increased the number of users to include automobiles, trains, transit, and land surveyors. The question is whether or not there is a better method for recovering the costs of GPS and other navigation systems that have widespread use. The Government will continue to study this issue.

B. Signal Availability

The availability of accurate navigation signals at all times is essential for safe navigation. Conversely, guaranteed availability of optimum performance may diminish national security objectives, so that contingency planning is necessary. The U.S. national policy is that all radionavigation systems operated by the U.S. Government will remain available for peaceful use subject to direction by the NCA in the event of a war or threat to national security.

C. Role of the Private Sector

Radionavigation systems have historically been provided by the Government to support safety, security, and commerce. These services have supported air, land and marine navigation and time or frequency-based services. For certain applications such as landing, positioning, and surveying, in areas where Federal systems are not economically justified, a number of privately operated systems are available to the user as an alternative or adjunct service.

Air navigation facilities, owned and operated by non-Federal service providers, are regulated by the FAA under Title 14 Part 171 of the Code of Federal Regulations (CFRs) "Non-Federal Navigation Facilities." Approximately 2000 non-Federal air navigation facilities provide air navigation services in the NAS. These include ILS, MLS, VOR, DME, NDB, Simplified Direction Finder (SDF), Transponder Landing System (TLS),

special Category I differential GPS (SCAT-I DGPS), and Automated Weather Observing System (AWOS) facilities. Non-Federal facility sponsors may be states, municipalities, airport authorities, airlines, companies, etc. Local benefit, like local economic development or increased business commerce, may justify the cost of installing and operating an air navigation facility even though the benefit accrued at the Federal level does not. A non-Federal sponsor may coordinate with the FAA to acquire, install and turn an air navigation facility over to the FAA for maintenance because waiting for a Federally provided facility would cost too much in lost business opportunity. Non-Federal facilities are operated and maintained to the same standards as Federally operated facilities under an Operations and Maintenance Manual agreement with the FAA. This program includes annual ground and flight inspections of the facility to ensure that it continues to be operated in accordance with this agreement. When the facility is available for public use, ground and flight inspections are provided without compensation, but reimbursement of these expenses must be sought if the facility only supports private operations.

The number of non-Federal services provided may increase as air navigation facilities lose eligibility for continued Federal subsidy. This occurs when the benefit accrued at the Federal level is lower than the cost of continuing to provide the service. The local benefit may be greater, however, prompting a non-Federal sponsor to assume the role of continuing to provide this service. For example, the FAA's predecessor, the Civil Aviation Authority (CAA), acquired almost 2,500 airway light beacons from 1926 through the late 1950s. Although the FAA dismantled the system with the replacement of radio ranges with VOR/DME and VORTAC, the state of Montana still owns and operates 17 of the Federally acquired visual airway beacons.

Commercial development of air navigation facilities is filling an increasing role in meeting both Federal and non-Federal service provider needs. A number of factors have converged to make privately funded commercial development attractive. The end of the "cold war" has opened up rapidly growing markets for air transportation services throughout the world. This has increased the market opportunities outside the United States. Commercial components have replaced military components, so the Federal version and the commercial version of the air navigation facility are identical. New development efforts have been privately funded to support non-standard facility types. Commercial development of standard type facilities (NDB, DME, ILS, then portable ILS receiver (PIR)) preceded Federal acquisition. Differential GPS systems were commercially developed to support Special Category I (SCAT-I) procedures. With the development of International Civil Aviation Organization (ICAO) standards for LAAS, a commercial development of Category I LAAS is proceeding the public/private partnership funded Category II/III LAAS development program. The Transponder Landing System (TLS) was privately developed to support Category I operations, without aircraft modifications, authorized under a Special Category I procedure.

A number of factors need to be considered when examining private sector involvement in the provision of air navigation services:

- Consideration of phase-over to private operation as a viable alternative to phaseout of a Federally operated radionavigation service.
- Private sector development of air navigation facilities for both non-Federal and Federal use.
- Impact of privately operated services on usage and demand for Federally operated services.
- Need for a Federally provided safety of navigation service even if commercially provided services are available.
- Liability considerations for the developer, service provider, and user.
- Radio frequency spectrum issues.
- Certification of the equipment, service, service provider, operator, and controller.

B.6 International Considerations

Radionavigation services and systems consider the standards and guidelines of international groups, including NATO and other allies, ICAO, the International Telecommunications Union (ITU), and the International Maritime Organization (IMO).

The goals of performance, standardization, and cost minimization of user equipment influence the search for an international consensus on a selection of radionavigation systems. The ICAO establishes standards for internationally used civil aviation radionavigation systems. The IMO plays a similar role for the international maritime community. The International Association of Lighthouse Authorities (IALA) also develops international radionavigation guidelines. IMO is reviewing existing and proposed radionavigation systems to identify a system or systems that could meet the requirements of, and be acceptable to, members of the international maritime community.

In planning U.S. radionavigation systems, consideration is also given to the possible future use of internationally shared systems. The Foreign Minister of the Russian Federation has offered the use of GLONASS on behalf of Russia to both IMO and ICAO. Both ICAO and IMO have accepted this offer. The U.S. supports the ICAO position.

In addition to operational, technical, and economic factors, international interests must also be considered in the determination of a system or systems to best meet civil user needs. Further international consultations under the auspices of the Department of State will be required to resolve the issues.

Department of State responsibilities for international cooperation on GPS are discussed in Section A.4.

B.7 Radio Frequency Spectrum Considerations

Radionavigation services are major users of the radio frequency spectrum in the United States and worldwide. Robust and satisfactory radionavigation services require adequate

spectrum bandwidth, with the highest level of integrity and availability. Spectrum engineering and spectrum policy for radionavigation systems operated by the Federal government are key elements that support the Federal radionavigation systems planning process. Spectrum policy for DOT is coordinated through OST.

The certification and use of radionavigation services is the shared responsibility of the DOD and DOT with delegation of spectrum responsibilities to the FAA, USCG, and DOD frequency management authorities. A key element in the certification of a navigation system is electromagnetic compatibility analysis, which helps determine its operational criteria and protection limits (e.g., power, channel spacing, spurious emissions, and total bandwidth).

The FAA, DOD, and the USCG are Federal users of spectrum as providers and operators of radionavigation services. The FAA use of spectrum is primarily in support of aeronautical safety services used within the National Airspace System (NAS). This exclusively allocated spectrum must be free from interference due to the safety of life aspects of FAA services. The USCG also uses spectrum as a provider of radionavigation systems. These systems include differential GPS beacons (285-325 kHz), Loran-C (90-110 kHz), maritime radiobeacons (285-325 kHz).

The White House Commission on Aviation Safety and Security recognized the importance of radio spectrum to our Nation's air traffic control system when it directed the FAA to develop a plan to ensure that, "the FAA's spectrum needs during modernization are not compromised.” In response, the FAA conducted a broad study, and released its final report on February 12, 1997 (Ref. 13). This report provides information on aeronautical radio systems and frequency bands, existing and predicated problems concerning them, and details a frequency plan, which can support these emerging aviation technologies and architectures.

The DOT (FHWA, FTA, and NHTSA) is developing Intelligent Transportation Systems (ITS) in conjunction with the private sector and state and local governments. Many ITS applications will make use of GPS and other radiodetermination systems and will require communication links to transmit DGPS corrections and location information in an integrated systems context. The ITS program is striving to make use of existing services wherever possible. However, some spectrum for ITS purposes will most likely be necessary.